THE FITNESS OF THE ENVIRONMENT

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When Darwin first turned the search-light of his genius upon the world of Nature, and under its illumination men were compelled to replace their static views of organic creation by a dynamic representation that made the history of life a connected and, in great part, progressive process from the beginning, attention was mainly concentrated on the fitness of the organism to its environment. The fact of such fitness had long been obvious in differing degrees, but the problem of its causation as a factor in survival was then for the first time philosophically treated in the doctrine of Natural Selection. Nevertheless, it must be admitted that through all the earlier discussions that ranged round these topics the point of view was more or less one-sided. The fitness of the organism to its environment was stressed and stressed again; the question of the fitness of the environment to the organism was seldom raised, or even realized. In some cases, along with views advancedly transmutational, a conception of the environment was maintained that was almost static. The organism, isolated from its environment, was ransacked for its history in the laboratory or made the subject of experiment in order to elucidate its behavior. The conception of the organism and its environment as vitally and reciprocally connected, as a single system undergoing change, had not yet been reached. This does not mean that certain broad features of mutual adaptation and compensation between environment and organism were not appreciated, and even some-

times doctored into dubious demonstrations of divinity. The writer has some recollection of an apologetic lecture delivered seventeen years ago by a man of justly international reputation, although on other grounds, who detailed the composition of the atmosphere as then known, and argued for the existence of God in that it was not "sticky," and that, while animals were all the time breathing out carbonic acid gas and taking in oxygen, plants were engaged in the reverse process. With greater breadth of detail and a more admirable logic, attention had been directed even earlier in some of the famous Bridgewater Treatises, concerned as a series with "the Power, Wisdom, and Goodness of God, as manifested in the Creation," to the remarkable and in some instances unique properties of water, air, and the ether in their relation to the maintenance of life. Yet the conception of fitness was usually that of an externally arranged environment, prepared in complete detachment from that which was, just as extraneously, later introduced to inhabit it. There was little thought of a close and mutually determined development of organic and inorganic after a stage in which the latter by obvious history had become fitted to be at once part-parent and cradle of life.[1]

It was inevitable, however, that with advance in understanding of the characteristics of the essential elements in the environment of living things, the degree of the capacity of these elements to serve in this respect should come into clearer light, while the rise of biochemistry made it impossible any longer to treat as of secondary importance their rôle when incorporated in the organism. But, in particular, the immense elongation of the environmental history as the results of modern spectroscopy and astronomical physics—the realization that the

[1] There have been of course many notable exceptions to this statement, as, e.g. A. R. Wallace, Man's Place in the Universe.

elements so essential to life had themselves undergone a long process of evolution—has gradually forced into the foreground the suggestion of the mutually unique fitness of environment and organism. Urged with keen logic and supported by a wealth of original research, this is the thesis of a recent brilliant study by Professor L. J. Henderson of Harvard.[2] "Darwinian fitness is compounded of a mutual relationship between the organism and the environment. Of this, fitness of environment is quite as essential a component as the fitness which arises in the process of organic evolution; and in fundamental characteristics the actual environment is the fittest possible abode of life."[3]

So daring a proposition could only be based on a restricted sense of the term "environment" as ordinarily understood, and it is at once made clear in the volume in question that this superlative fitness is only asserted of those physico-chemical elements that are ordinarily associated with life, and, further, this fitness is considered only with reference to a certain restricted series of organic characteristics. In fact the investigation is narrowed down to this specific inquiry: "To what extent do the characteristics of matter and energy and the cosmic processes favor the existence of mechanisms which must be complex, highly regulated, and provided with suitable matter and energy as food?"[4]

It may be at once admitted that the detailed answer to this question as based on modern chemistry is singularly impressive. The progress of science has served only to accentuate what was already known and to bring out even more profound correspondences and mutual relations between the organism and its environment. Further, the realization of the import of these data tends to the reconsideration of cognate problems, such as the

[2] The Fitness of the Environment, an Inquiry into the Biological Significance of the Properties of Matter (The Macmillan Company, 1913).

[3] P. v. [4] P. 37.

origin of life, while the whole series of phenomena calls for an interpretation. None of these topics has been overlooked in Professor Henderson's treatise.

Let us first consider the nature of the evidence. Of substances necessary to life, water perhaps holds the first place. In some instances the bodies of organisms are composed of it to the extent of ninety per cent, and as an actual organic medium it occupies about three-quarters of the surface of the earth. Because of its very high specific heat, all bodies of water have a tendency to maintain a nearly constant temperature, while the comparative moderation of summer and winter temperatures, and the promotion of marine currents and winds are directly and indirectly in part connected with the same fact—effects which go to make the earth peculiarly habitable. The same property is of extreme importance, further, in regulating the heat of the human body, of which water is the chief constituent; because of the high heat-capacity of water, man's exertions do not raise the temperature of his body as they would if it were otherwise composed. And in all these respects water has a fitness shared only by ammonia, which in other vital relations is far inferior.

Again, the freezing point of water, although low to the human organism, is really very high compared with that of similar substances; ammonia, for example, freezes at 75° Centigrade, a point at which most of the chemical activity known to us would cease. On the other hand, water cannot get colder than 0° Centigrade, however much heat is abstracted; that is, the cooling of oceans and lesser bodies of water is limited by its freezing point. In connection with the extraordinary evaporation going on over the surfaces of water, "no other liquid could . . . bind so much (latent) heat; no other vapor could yield so much heat upon condensation."[5] In these last two characteristics, as in certain meteoro-

[5] P. 102.

logical relations, water produces maximum beneficent effects as compared with all other substances. Further, its unique quality of expanding when cooled at temperatures near the freezing point brings a whole train of benefits in its wake. As a solvent nothing can compare with water, and, gases apart, practically all the food of plants and animals is water-borne. Water has also the greatest surface tension of all liquids with the exception of mercury, a fact of peculiar importance in connection with the functioning of the colloidal structures in living matter.

Massed, as the ocean, it is further significant. Practically constant today in temperature, alkalinity, and concentration, this character of constancy is even more important biologically in relation to the chemical composition of sea-water. Of all balanced solutions of salts, "sea-water is by far the best." The constancy of the osmotic pressure of sea-water is another biological factor of primary importance, while the size, the mobility, the richness and varied nature of its constituents, all make the ocean uniquely adapted to life. In connection with the question of origin it is important to note, as Professor Macallum of Toronto first pointed out, that there is a quantitative correspondence between the various saline constituents of sea-water and mammalian blood which is more than accidental, while the regulatory processes of ocean and of organism, although differing greatly in degree, are not dissimilar in one or two respects, e.g. temperature-regulation by evaporation, and regulation of alkalinity. "Is it not possible," asks Professor Henderson, hinting at a point of view developed at a later stage of his study, "that in the case of the organic processes some have now and then been regarded as adaptations which in reality arose automatically and quite inevitably?"[6] Waiving the question for the moment, we are confronted with the basal fact that in practically

[6] P. 189.

every particular no other known substance could take the place of water in its various massed arrangements and meteorological phases without grave restriction of vital possibilities as we know them. Nothing can even approach it in fitness as an environmental factor.

Yet water is not alone in possessing a marked fitness for the life-cycle. Carbonic acid gas,[7] because of its unusual solubility, is "the one substance which in considerable quantities relative to its total amount everywhere accompanies water;" indeed the two together make up "the real environment." Extraordinarily useful as a food with its maximum mobility and all-pervasiveness, carbon dioxide, because of the precise degree of its weakness as an acid, further has the remarkable and unique property "of preserving a neutral reaction whenever it exists in solution with its salts, provided there be an excess of acid." To this is due the characteristic chemical inactivity of water, which is all the more wonderful, since "acidity and alkalinity surpass all other conditions, even temperature and concentration of reacting substances, in the influence which they exert upon many chemical processes." Almost entirely as the result of this mechanism the oceans are always nearly neutral, and protoplasm and blood possess an unvarying reaction. In connection with the last circumstance an interesting theoretical point emerges. The equilibrium between carbon dioxide and bicarbonates has a first place in the regulation of the reactions both of blood and of protoplasm. Now this significance of carbon dioxide is not an adaptation, for "natural selection can have nothing to do with the occurrence of CO_2 in the living organism, or, presumably, with the nature of the original living things upon the earth." In the day of few things, carbon dioxide was there and simply had to be a constituent of primeval life.

[7] Now usually known as carbon dioxide.

Very naturally, out of the interactions between water and carbon dioxide arises the study of the infinity of compounds into which their elements—carbon, hydrogen, and oxygen—can be transformed. Here the demonstration of fitness for life becomes more technical, but none the less impressive. Carbon compounds are unique not merely because they are numerous; "they are uniquely numerous because they are compounds of carbon with hydrogen, oxygen, and in some cases certain other elements,"—compounds unique and peculiar in their chemical relationship, resulting, for example, in the stability of complex organic substances. No other elements apparently can readily form compounds comparable in number, variety, complexity, and capacity for chemical change, with those of the elements under consideration. That the very elements which make up water and carbon dioxide, and apparently they alone, should possess these wonderful properties, is, to say the least, very remarkable. Without the burden of detail it may be stated that there is a basal transformation which underlies the life of plant and animal alike; whereby in the laboratory of the leaf-cell by means of solar energy, the carbon dioxide of the atmosphere and water are reduced, so that a carbohydrate, sugar—in reality a system comprising some two hundred substances of great chemical activity—is formed with liberation of the oxygen and storage of energy. "This is the one chemical process which is open, if any transformations whatever are to be accomplished with carbon dioxide and water; and this leads directly and to all appearances necessarily to the greatest chemical complexity that has been found in any one chemical process." It leads, in short, to the full intricacy of organic chemistry, and that, so far as can be seen, as the result of the native properties of the three elements. Finally, in connection with the reductions and oxidation that go to constitute the vital transfor-

mations of energy, it appears that carbon and hydrogen make good reservoirs of energy to be liberated by oxidation; that oxidations are the best chemical source of energy (reactions with fluorine excepted); that reductions are the best means of storing energy by chemical processes; and that amongst possible oxidations and reductions, those of hydrogen especially, and then those of carbon, are associated with the largest transformation of energy. In other words, "the very chemical changes which for so many other reasons seem to be best fitted to become the processes of physiology, turn out to be the very ones which can divert the greatest flood of energy into the stream of life; and these are the reactions automatically provided for by the cosmic process."[8]

Water and carbon dioxide, occurring in vast quantities outside the crust of the earth, have then both in themselves and in compounds formed from rearrangements of atoms of their component elements a maximal number of qualities, many of them unique, for coöperation in the complexity, regulation, and metabolism of life. What reflections, rather than conclusions, may be suggested by this and the cognate data that have been outlined above?

To begin with, they certainly bring the inorganic and the organic into the closest of relationships. The former is shown to consist initially of a nebula composed of a comparatively small number of "proto-elements," which increase in number and gradually evolve into the elements of modern chemistry. At a certain stage in the history of the planet into which this primal nebular condition cools and concentrates, life draws into being, at first, let us suppose, in specific colloidal molecules. The material connection appears to be so direct that the differentia must be energetic. This is not, however, the view taken by Professor Henderson. "There is certainly no reason to ascribe greater importance to energy than

[8] P. 248.

to matter in the vital processes."[9] On the contrary, we believe there is every reason. The sole difference between a living cat and the same creature a moment after death is an energetic one—not quantitative, but in the control and direction of its stock of energy. The energy of the dead cat is dissipated by heat-radiation and slow combustion of the tissues; that is, it flows along paths which are determined by external agency, and in time a state of equilibrium is reached. The energy of the living cat flows along paths which are only indirectly determined by outside conditions. Fling it up alive, and it will always land on its feet; fling it up dead, and it will come down "any old way." Further, the organism is a centre at which the ordinary tendency to degradation of energy is resisted, while the phenomena of reproduction and of consciousness, of which no energetic explanation is at present possible, are left entirely out of consideration.

"Energy, like matter, is in general well known to us. Its manifestations are few, and they are universal."[10] Again, we would, on the contrary, maintain that in the light of present knowledge we know much more about matter, and the knowledge is different from that in regard to energy. Of the latter there is no thoroughgoing theory available. The older teaching laid down a division into energy of motion (kinetic energy) and energy of position (potential energy). Some of the stock examples of the latter are not, however, forms of energy at all, but only, as Professor Benjamin Moore says, "potentialities for the development of energy,"[11] as in the case of water stored at a height. Beyond the important fact that measurements of different forms of energy in different units bear a constant relationship to one another, little is known as to what is actually in-

[9] P. 299. [10] P. 18.
[11] The Origin and Nature of Life, p. 36.

volved in the transformation of energy; whether in some cases it is an actual transformation at all or merely an exchange comparable to that which obtains at the merchant's counter. Further, the doctrine of its conservation, while demonstrably true of certain closed systems, can only be extended to the universe by a gigantic act of faith conveying at the same time data inconsistent with the doctrine.[12] It is even probable that in the ultimate analysis matter is electrical, that is, energetic, in origin; that the ether, particulate or non-particulate—more probably the latter—when associated with energy, serves to produce the electron, the initial visible stage in the creation of matter. But the *sine qua non* would appear to be an eternal source of creative energy which, operative as kinetic energy, thus produces matter of lowest atomic weight, into whose units it packs itself as potential energy. In the furnace of a nebula such a process, it may be, is in operation with constancy, and likewise with critical pulses of action that have issued in the distinctive features of cosmic history.

A further reflection connected with this historically evolved environmental fitness concerns itself with the question of the moment of the origin of life. In the masterly address of Sir Edward A. Schäfer, President for 1912 of the British Association for the Advancement of Science, the opinion was hazarded that "the possibility of the production of life—that is, of living material—is not so remote as has been generally assumed"; while the conclusion was held to be "forced upon us" that "the evolution of non-living into living substance has happened more than once, and we can be by no means sure that it may not be happening still." The fact, however, that life even in its simplest manifestations is invariably organized, together with the full understanding of what is

[12] Cf. G. W. de Tunzelmann, God and the Universe, pp. 90–97; Sir Oliver Lodge, Life and Matter, p. 22.

implied in the conception of a history of life, namely, that not merely life itself but the environment of its production and evolution have been correlatively subjects of a broadly progressive change, makes it difficult to believe that life will return upon itself, so to speak, even in the laboratory of the experimenter. A specific moment came when the organic colloid became possible, infinitely more complex than its antecedent inorganic relative, and characterized by marked lability, which means just so much more sensitivity to external stimulation. Even if we assume that inorganic colloids were first capable of formation at the time of the deposition of the sedimentary rocks when the temperature of the crust had already fallen to just under 100° Centigrade, the organic colloids came into existence shortly after that at a definite stage in the history of our earth, when many conditions were very different from the present and absolutely irreproducible. The ocean, for example, has grown colder and more saline since that era; its reaction has changed from faintly acid to faintly alkaline. The amount of carbon dioxide in the atmosphere has been enormously reduced since those days, and the sun is colder. In short, conditions of temperature, atmosphere, possibly even in some measure of chemical affinity and electricity, were greatly different, and in view of the peculiarly close relation and adaptation of every form of life to its environment it seems unphilosophical to look for the origin of life other than in the precise phase of planetary development under which it first arose. No form of life, once extinct, has, so far as we know, again appeared, and only in the most superficial of senses can it be said that history repeats itself.

There is, finally, a primary quality of environmental fitness, prior to the appearance of life, and therefore not due to the action of natural selection—an antecedent adaptation. Has this merely happened so, or is it in

the nature of a prepared environment? It is an old question, whose complete and final answer in terms of knowledge is unattainable on this stage of existence. There is absolutely no doubt that Professor Henderson is right in asserting that "Science has finally put the old Teleology to death."[13] The question remains whether she has not supplied us in return with a teleology farther-reaching and more profound. Strictly, this may well be a question for the philosopher rather than for the man of science. *Qua* man of science, the latter is perfectly within his rights in holding to a mechanistic interpretation even as an ideal; he is only wrong when he pretends that even an approximation has been reached in the interpretation of life or its environment in terms of mechanism alone. From such assumption the volume in question is scrupulously free. Indeed, it is explicitly stated that there is "not one chance in countless millions of millions" that the many properties of carbon, hydrogen, oxygen, and their compounds, uniquely favorable to life, should occur simultaneously other than through the operation of a natural law which somehow connects them together.[14] The illuminating conclusion is even drawn that "logically, in some obscure manner, cosmic and biological evolution are one." It is one process yielding results not merely contingent, but "resembling those which in human action we recognize as purposeful." Yet of all this "an explanation is to seek; none is at hand."

It would not be difficult even in this balanced work to point out instances where use of the mechanistic interpretation simply covers a begging of the question at issue.[15] A more important matter is whether "lacking any indication of what such an explanation may be, or how it is to be sought," it is of any practical use dogmati-

[13] P. 311. [14] P. 276 ff.

[15] Cf., for example, the sentence in conclusion of a paragraph, beginning "It is easy to see that, given an enzyme possessing the power to select," etc., p. 231.

cally to insist that even for science the explanation "must be purely mechanistic."

After all, the main question about an interpretation is not whether it is strictly supernatural or metaphysical or mechanistic, but whether it is complete, or even ever likely to be so under the limitations of the method pursued. It is only utility that makes us artificially speak of "the world of science." The world is one. And there is no limitation in the neo-vitalistic hypothesis that may not be matched by a corresponding one in mechanistic explanation, while the latter can never in any case be final when applied to life, since, as Oskar Hertwig long ago pointed out, it takes no account of the activity of the organism itself, the maintenance of which is the creature's object.[16] The mechanical indifference of parts, as in an engine, is replaced by an "organic consensus." On the other hand we consider that it is inexact to say that in vitalistic speculations "the properties of matter and the process of cosmic evolution have no place."[17] They have as much place as in any other explanation. What in any case is chemical affinity? Something that, intangible by ordinary methods yet demonstrable in its results, is to that extent akin to the directive tendency which the neo-vitalist finds necessary to supplement his explanation of certain massed results in the realm of life.

As already stated, Professor Henderson definitely realizes the limitations of mechanistic views. "Mechanism can never explain, cannot even face the problem of the existence of matter and energy."[18] He even thinks it may be necessary to postulate "a bent, a direction of flow or development," in inorganic nature as in organic. But this philosophical excursion seems risky, and towards the close of the book he retires again within the scientific

[16] Cf. J. S. Haldane, Mechanism, Life, and Personality, Chapter II.
[17] P. 296. [18] P. 309.

compound, and puts his mind at rest by turning his back, to use his own phrase, on ultimate problems. "It is certain that physical science needs no teleology to explain its phenomena and processes." This may be true of any stage considered in isolation, with its prepared matter leading on to another stage; but it is hardly true of the whole, when we consider its character, to what it leads, and the simple fact that it does so lead.

This, however, is to enter "the realm of ends," to ask for a thorough-going exposition and criticism of causality, and to seek for a standard by which the advance or retrogression of various stages may be measured. All this and more will be found in Professor Hobhouse's "Development and Purpose," which, in thesis and treatment at least, makes a profounder appeal; for, while Professor Henderson considers evolution to be biocentric, Professor Hobhouse argues that it is psychocentric. He thinks that it "can be best understood as the effect of a purpose slowly working itself out under limiting conditions which it brings under control."[19] Or, as it is more conclusively phrased on another page: "There is a spiritual element integral to the structure and movement of Reality; and evolution is the process by which this principle makes itself master of the residual conditions which at first dominate its life and thwart its efforts."

Thus to seize on the most distinctive feature or product of a process and endeavor through its aid to arrive at some interpretation of the whole, gives greater promise of success than a method which, mechanism-bound, must continually work backwards rather than forwards for the limited explanation that in the end it can afford. Such a view alone has any prospect of being able to relate the empirical order to the underlying conditions of reality. It will further furnish us with at least some palpably plausible explanation of the environmental fitness for which on terms of strict mechanism "existing knowl-

[19] P. xxvi f.

edge provides no clew." For it is nothing less than the insistence that a purpose is at the core of the world-process, conditioned it may be, at least to begin with, yet ever coming into fuller and completer expression of that Reason which is the ultimate cause of the various correlations and concomitances disclosed by the process. In its revelation of increasing values as characterizing the graded stages of evolution, as well as in its recognition that the future equally with the past may truly be said to be determining the actual present, it has an outlook that extends beyond the purely mechanical explanation with its naïve, linear conception of causation, indifferent to concomitants, to values, to ends. Not merely does the mechanical view fail to meet the demands of science; it does not satisfy the spiritual cravings of man.

A reconstruction both conceptual and experiential accordingly is called for, whose final secret Professor Hobhouse considers to lie "in the consciousness of development itself. . . . The essence of this reconstruction is the entry into the sphere of consciousness, previously concerned only with results, of the data and the processes by which results are obtained." This in turn, we believe, must inevitably lead to a spiritual interpretation of nature, based upon the environmental fitnesses detailed above and upon the gradual awakening and uprising of consciousness till it becomes not merely conscious of its life as a unity, but of the conditions under which it has come into being, and, controlling these, moves with a straighter course to the as yet dimly appreciated goal. Natural selection, which represents the play of physical forces and of life itself upon its own advance, gradually loses its force as the methods of that play are better understood and so controlled. That which was implicit in the process becomes more and more explicit, and more important and determinative; that which was operating

on consciousness increasingly becomes an object of consciousness, as the ultimate Reason, the basis of the persistent law and order of the universe, shows forth more and more of itself in human personalities and society, thus bringing their lives into ever-increasing harmony with one another and with itself. The individual's highest response to this transcendent influence and appeal lies in becoming like that which thus influences and appeals. So to think is to recognize in the words of the ancient seer no rush of rhetoric but a profound glimpse into the heart of things: "For thus saith the Lord that created the heavens; he is God; that formed the earth and made it; he established it, he created it not a waste, he formed it to be inhabited."[20] It is also to acknowledge the essential fitness of the apostolic injunction: "Work out your own salvation. . . . It is God that worketh in you."[21]

[20] Isa. 45 18. [21] Phil. 2 12, 13.